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An Experimental Investigation on the Characteristics of Cylindrical Plunge Dry Grinding with Structured cBN Wheels

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Abstract

This paper proposes a new innovative concept approaching the optimum cylindrical plunge dry grinding. The concept is based on the individual dressing operation in order to create designed structures on the grinding wheel surface. Cylindrical plunge dry grinding experiments have been carried out by employing both structured wheels and normal wheels. The results show that dry grinding with the structured wheel leads to lower grinding forces, area-specific grinding energy, and thermal damages to the workpiece as compared to the case of grinding with the normal wheel. The relatively higher surface roughness values, although, were resulted in the case of applying the structured wheel, they may be lowered by an additional spark-out pass to the values obtained with using the normal wheel.

Keywords: grinding; dressing; wheel structuring; CBN wheel; dry grinding

1. Introduction

Due to the increasing costs for supplying coolant-lubricants and the demand for environmental friendly machining process, the dry grinding has lately become a subject of special interest. Accordingly, various attempts are being made to realize dry grinding [1-6].

Despite these interests and attempts, dry grinding is not much employed in industrial environments due to its economic inefficiency caused by additional required devices and high rate of the deteriorated parts owing to the thermal damages.

In order to perform an efficient dry grinding process without thermal damages, the chip formation needs to be optimized so that the friction between the grinding wheel and the workpiece is minimized. Optimal chip formation depends on the workpiece material and grinding parameters as well as the grain size. The optimal chip size largely depends on the number of active grains. In order to minimize the number of active grains, a new concept using the structured grinding wheels has been developed in the last few years. The new concept is based on the reduction of static cutting edges through creating a special structure on the wheel surface. The structured contact layer may lead to the lower cutting forces, process power consumption and heat generation in the contact zone. The results obtained through several experimental investigations [7-9]. Suggest the dry grinding with special structured wheels as a promising method to approach the optimum dry grinding operation.

This paper presents an experimental investigation on the characteristics of cylindrical plunge grinding with structured cBN wheels.

2. Creation of the structure

Figure 1 shows the schematic of the external cylindrical plunge grinding operation by a normal grinding wheel and a structured grinding wheel. The form of the structure, showed in this figure, is an example amongst various structures which may be

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created on the wheel surface through an individual conditioning.

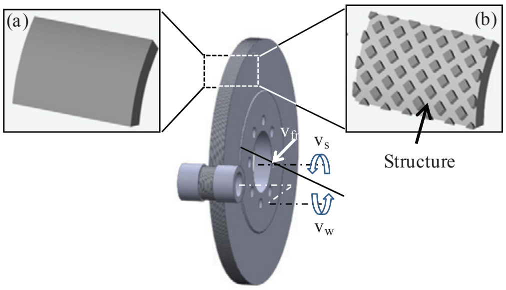

Fig. 1. Schematic views: (a) normal grinding wheel with full contact layer, (b) structured grinding wheel with reduced contact layer

The desired structures on the wheel surface are created by individual setting of the dressing kinematic parameters consisting of the shape of dresser, dressing depth of cut, a_{ed}, and the dressing feed, f_{ad}. As illustrated in figure 2, the wheel is flattened under ordinary dressing conditions (step 1).

On the flattened wheel surface, the desired structure is created through a special conditioning, in which the dressing feed, f_{ad}, is set bigger than the active width, b_d (step 2). The most important point in this step is that the operational parameters ($f_{ad\text{-}stru.}$ and $a_{ed\text{-}stru.}$) in special conditioning must be bigger than those in dressing (f_{ad} and a_{ed}).

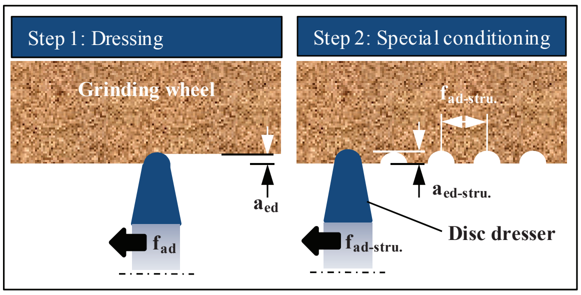

Fig. 2. Schematic overview of contact layer before and after structuring

3. Experimental setup

The experiments to evaluate the effects of employing the structured wheels on the efficiency of dry grinding were performed on a cylindrical grinding machine from EMAG Salach Maschinenfabrik GmbH company, model “HG 204 S”. The workpiece was fixed on a rotational dynamometer (Kistler Instruments company) assembled on the workpeice spindle. The dynamometer is able to measure three orthogonal forces (F_x, F_y, F_z) and the torque around the Z axis (figure 3). The surface roughness of the workpiece was measured with the surface roughness measurement instrument from the Hommel-Etamic GmbH company, model “Wave system™ Hommel Tester T8000”.

The cBN grinding wheel (vitrified) with an outer diameter of 400 mm and a width of 15 mm was used to grind a bearing steel (100Cr6, HRC 62±2) with an outer diameter of 60 mm by the cylindrical grinding machine. The test conditions during grinding process are listed in table 1.

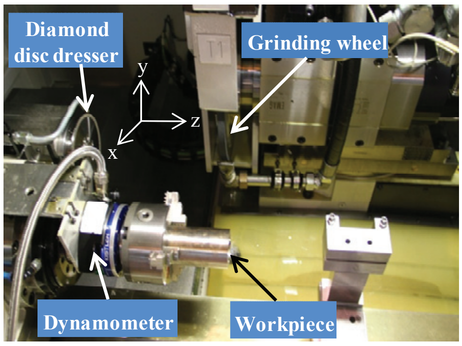

Fig. 3. Experimental set-up for cylindrical plunge grinding

Nomenclature

a_{ed}	depth of dressing cut
$a_{ed\text{-}stru.}$	depth of dressing cut for special conditioning
b_d	active width of dressing tool
d_s, d_w	grinding wheel and workpiece diameter
E''_c	area related grinding energy
f_{ad}	axial dressing feed (per wheel revolution)
$f_{ad\text{-}stru.}$	axial dressing feed for special conditioning
F'_n, F'_t	specific normal and tangential grinding force
q_d	dressing speed ratio
q_s	grinding speed ratio
Q'_w	specific material removal rate
R_a, R_z	average roughness and mean peak-to-valley height
t_a	spark-out time
U_d	dressing overlap ratio
v_{fr}	radial feed rate
v_s	grinding wheel circumferential speed
v_w	workpiece speed
z	stock removal

Table 1. Experimental conditions

Parameters	Data
Grinding wheel	B126 C125 (vitrified)
	d_s = 400 mm
Workpiece	100Cr6, HRC 62± 2
	d_w = 60 mm
Grinding parameters	Q'_w = 0.5 - 12 mm³/mm·s
	q_s = -180 (up grinding)
	v_s = 60 m/s
	v_w = 0.33 m/s
	z = 0.04 mm
Dressing parameters	a_{ed} = 3 µm
	b_d = 0.426 mm
	q_d = +0.8 (down dressing)
	U_d = 4
Grinding process	dry and wet grinding (grinding oil)

4. Results and discussion

4.1. Effects of the reduced contact layer

Figure 4 illustrates the effects of the reduced contact layers with 25%, 50%, 75% and full contact layer on the specific grinding forces at the specific material removal rate of Q'_w = 9 mm³/mm·s in dry grinding. It can be seen that reduction of the contact layer leads to reduction in specific grinding forces. The reduced contact layer leads directly to the increase of uncut chip thickness and proportion of the cutting regime. This figure also shows that the grinding forces in grinding with a structured wheel can be influenced by the percentage of the contact layer. The normal specific grinding force, F'_n, is reduced from 3.8 N/mm in 75% contact layer to 2.7 N/mm in 25% contact layer. This is caused by the higher active grains when the contact layer is larger.

In figure 5, the influence of the reduced contact layers on the surface roughness parameters, R_a, R_z, at the specific material removal rate of Q'_w = 9 mm³/mm·s has been represented. It is clear that the finer surface roughness will be achieved using normal wheel with full contact layer comparing with the structured wheel with reduced contact layer. This can be due to the reduction of rubbing action, which improve the surface roughness, when grinding with the structured wheels. In other words, the chip thickness becomes relatively higher when the contact layer is decreased and the portion of cutting action is increased in grinding operation. As a result, higher surface roughness values appear on the workpiece.

This is confirmed by the figure 5 showing that the average roughness height, R_a, increases from 0.67 µm in the case of using the wheel with 75% contact layer to 2.76 µm in the case of using that with 25% contact layer.

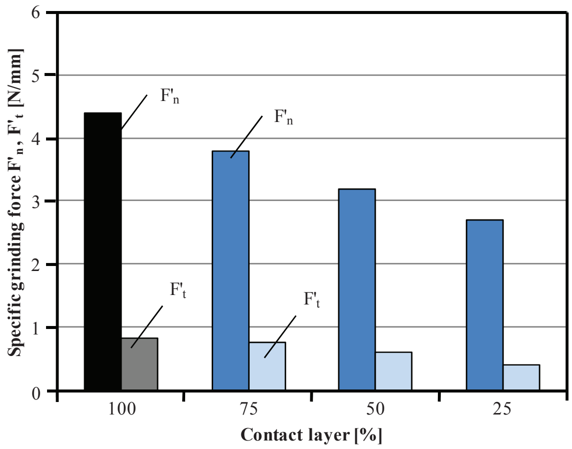

Fig. 4. The effect of the reduced contact layer on the specific grinding forces (Q'_w = 9 mm³/mm·s, dry grinding)

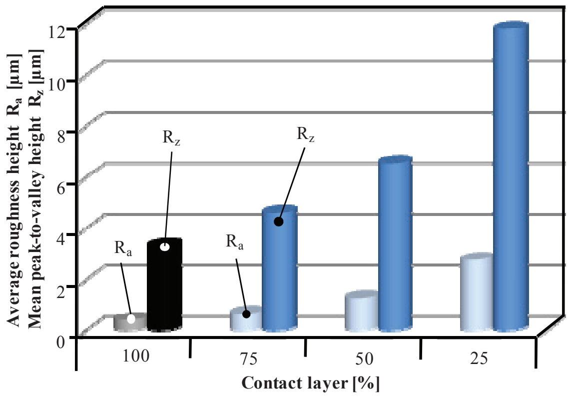

Fig. 5. Influence of the reduced contact layer on the surface roughness (Q'_w = 9 mm³/mm·s, dry grinding)

4.2. Thermal effects

In figure 6, the influence of the structuring of the CBN grinding wheel on the grinding forces for various material removal rates has been represented. In dry grinding with 25% contact layer the forces are lower as compared with grinding with 100% contact layer in both dry and wet grinding cases. As already mentioned, the reduction in grinding forces was caused by the new structure in which the number of kinematic cutting edges is reduced. This provides an optimized chip formation process.

The influence of the structuring on heat generation in the grinding contact zone can be determined by the area-specific grinding energy E''_c. The area-specific grinding energy is an energetic process parameter which describes the flow of energy into the component based on one unit area element and therefore can be used as a reference of thermal damages of the workpiece. As shown in figure 7, the area-specific grinding energies in grinding with 25% contact layer are almost in all the specific material removal rates much smaller than those in both dry and wet grinding with 100% contact layer.

Figure 8 shows the effect of reducing the contact layer on the visual thermal damage during dry grinding with 25% and 100% contact layers, and in the wet grinding with 100% contact surface at the specific material removal rate of Q'_w = 6 mm³/mm·s in dry grinding. The grinding burn marks appear in dry grinding with full contact layer, while no burn marks occurred in the case of dry grinding with 25% contact layer and wet grinding with full contact layer.

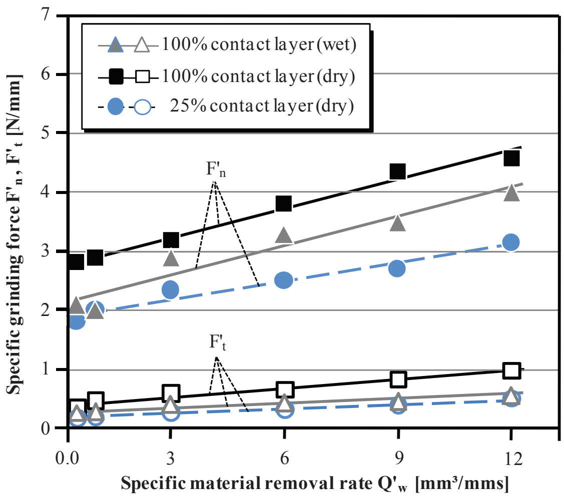

Fig. 6. Influence of the specific material removal rate, Q'_w, on the specific grinding forces (v_s = 60 m/s, q_s = -180, z = 0.04 mm)

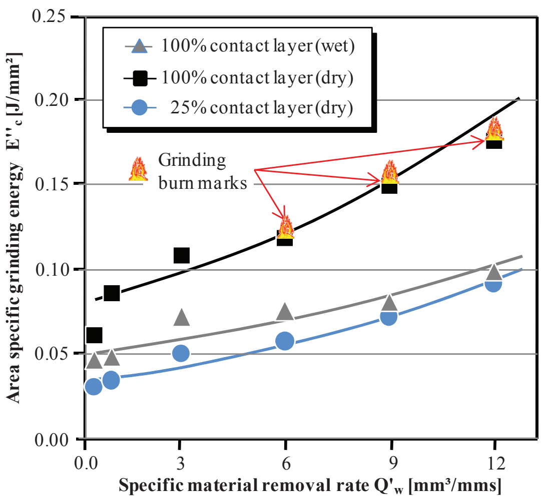

Fig. 7. Reduction of area-specific grinding energy caused by the structuring (v_s = 60 m/s, q_s = -180, z = 0.04 mm)

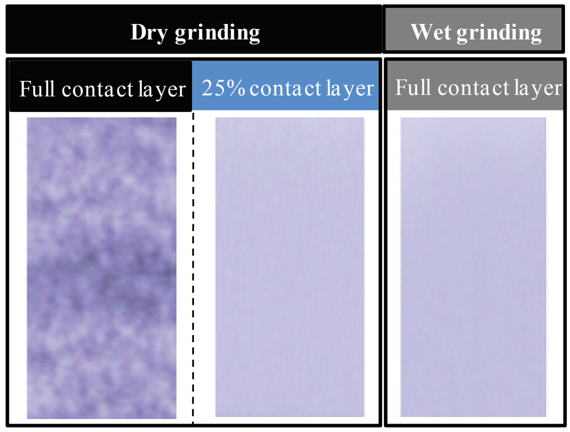

Fig. 8. The Influence of the reduced contact layer on thermal damages (cBN wheel, Q'_w = 6 mm³/mm·s, v_s = 60 m/s, q_s = -180)

4.3. Surface quality

Figure 9 illustrates how the workpiece surface roughness values can be influenced by structuring the grinding wheel. The results indicate higher surface roughness values of the specimens ground by the wheel with 25% contact layer compared with those ground using the wheel with 100% contact layer. This is caused by a smaller number of kinematic cutting edges and a larger resultant chip thickness when using the structured grinding wheel.

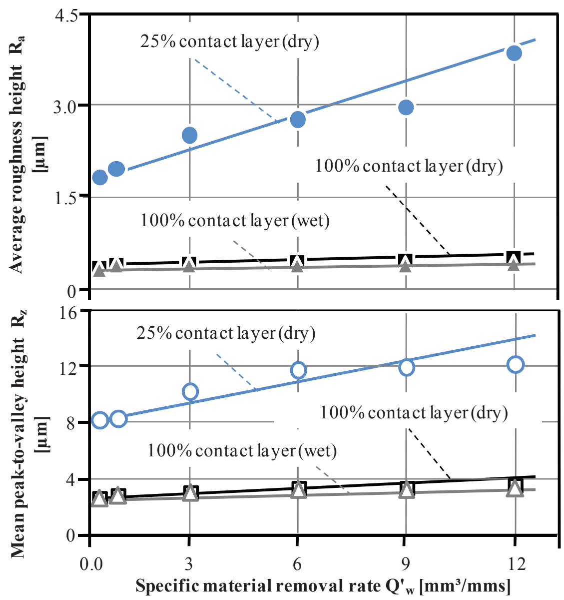

Fig. 9. The Influence of the specific material removal rate Q'_w on the surface roughness parameters, R_a, R_z (v_s = 60 m/s, q_s = -180, z = 0.04 mm)

The workpeice roughness, however, can be reduced by a spark-out process. A spark-out process is a special finishing process in which the feed rate is zero. The influence of the spark-out time on the surface roughness of the workpiece is presented in figure 10. It can be seen that the spark-out leads to a reduction in workpiece roughness values to a certain level, regardless of the workpiece roughness values before spark-out. This also leads to an increase in the process time.

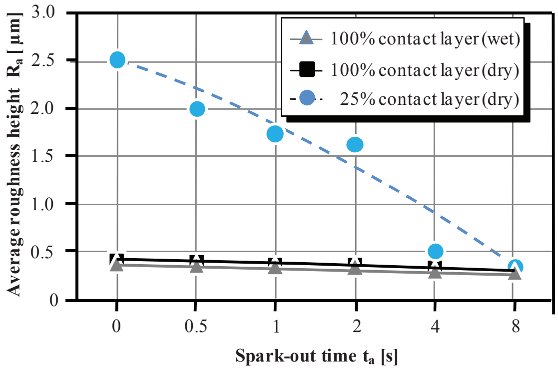

Fig. 10. Reduction of the surface roughness through the spark-out time (Q'_w = 3 mm³/mm·s, v_s = 60 m/s, q_s = -180, z = 0.04 mm)

5. Summary

In order to determine the effects of process parameters on the cylindrical plunge dry grinding with the structured cBN wheels, a systematic investigation have been carried out in this study. The results can be summarized as follows:

- The grinding forces and the area-specific grinding energy decrease with the reduction in the contact layer.

- The visible thermal damages in dry grinding with 25% contact layer appear in a higher specific material removal rate as compared with dry grinding with 100 % contact layer.

- The roughness values of the workpieces ground with the structured wheel are higher than those ground with the normal wheel. The workpiece roughness, however, can be greatly reduced by the spark out.

References

[1] Heisel U. Umwelt- und Arbeitsplatzbelastung durch Kühlschmierstoffe, Technische Rundschau, 1992; 84/26: 28–30
[2] Heisel U, Lutz M. Investigation of cooling and lubricating liquids, Production Engineering, 1993;1:23–6
[3] Tönshoff HK, Wobker HG, Brunner G, Kroos, F. Möglichkeiten und Grenzen des Trockenschleifens gehärteter Stähle, Härterei-Technische Mitteilungen, 1995; 50
[4] Brinksmeier E, Brockhoff T, Walter A. Minimalmengenkühlschmierung und Trocken-bearbeitung beim Schleifen, Härterei-Technische Mitteilungen, 1997; 52/3: 166–170
[5] Hoffmeister HW, Maiz K. Trockenschleifen mit Hilfe der Cryotechnik, 5. Seminar Moderne Schleiftechnologie und Feinstbearbeitung, Hrsg. T. Tawakoli, Hochschule Furtwangen university, 2004: 7/1–7/12
[6] Tawakoli T, Rabiey M. Trockenschleifen, Möglichkeiten und Grenzen, 6. Seminar Moderne Schleiftechnologie und Feinstbearbeitung, Hrsg. T. Tawakoli, Hochschule Furtwangen university, 2006; 3a/1–26
[7] Tawakoli T, Westkämper E, Rabiey, M. Dry grinding by special conditioning, International Journal of Advanced Manufacturing Technology, 2007; 33: 419–424.
[8] Tawakoli T, Rabiey M. An innovative concept and its effects on wheel surface topography in dry grinding by resin and vitrified bond CBN wheel, Machining Science and Technology, 2008; 12/4: 514–528.
[9] Tawakoli T, Lee DH, Rasifard A. Trocken-bearbeitung beim Rundschleifen, 8. Seminar Moderne Schleiftechnologie und Feinstbearbeitung, Vulkan-Verlag, 2010: 4c1/13